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Title of the Invention:

FUEL INJECTOR AND ITS CONTROL METHOD

Background of the Invention:

5 ~~<Field of the Invention>~~

The present invention relates to a fuel injector^{system} having a fuel injection valve, which is mounted in an internal-combustion engine to control the amount of fuel supplied^{to the engine}, and to a method of controlling the fuel^{injection valve} injector.

10 In general, a fuel injection valve comprises a fuel injection orifice, a valve seat disposed in^{the} vicinity^{of the fuel injection orifice}, a valve body slidably supported in an axial direction at^a position facing the valve seat, and a spring. The spring generates^a the force that presses the valve body in the direction of^{and into contact with} the valve seat^{so as to close the valve orifice}. Thus, while

15 ~~While~~ the valve seat and the valve body are ~~being~~ kept in ~~a~~ contact statusⁱⁿ by the spring force, that is to say, ~~under~~ the closed status of the valve, since the fuel passageway^{through the fuel injection orifice} is closed, fuel is not injected from the fuel injection^{valve} orifice.

The fuel injection valve also has a magnetic circuit and coil
20 assembly for driving the valve body. The application of a current to the coil assembly exerts^a magnetic attraction force on the valve body, ~~hereby~~^{causing} sliding the valve body^{to slide} in an axial direction, and ~~moving the valve body~~^{move} away from the valve seat^{thereby} to open the ~~valve~~^{fuel passageway through the fuel injection orifice}.

At this time, since the fuel passageway is opened, fuel is injected
25 from the fuel injection^{valve} orifice. ^{operation of such a} In the fuel injection valve, the amount of

fuel supplied can be controlled by adjusting the time ^{during} ~~for~~ which the open status of the valve is maintained.

To precisely control the amount of fuel supplied to the internal combustion engine, it is necessary to reduce the minimum amount of injection that ^{represents} ~~is~~ the minimal value of the controllable amounts of fuel ^{capable of being} ~~supplied~~. To achieve ^{such a} ~~the~~ reduction, the valve body needs to be opened at high speed, and ^{for this purpose} ~~and~~ ^{the} ~~hereby~~ supply of a current to the coil assembly needs to be rapidly started.

~~Prior Arts~~

10 A patent document 1 (Japanese Application Patent Laid-Open Publication No. Hei 08-45735) exemplifies the conventional technology related to the above ^{-described fuel injection valve operation}.

According to the patent document 1, in an electromagnetic load-driving method that uses at least one series circuit, which includes a load and a changeover means, changeover control is provided so that supply of a current to the coil assembly can be rapidly started by setting ^a small resultant inductance for a first time interval, in other words, for valve opening, and ^a ~~so that~~ ^{is then} large resultant inductance ~~can be~~ set for a second time interval, ^{which represents} the valve-opening retention duration, following the above-mentioned first time interval.

Summary of the Invention:

Under the conventional technology described above, ~~however~~ ^{the} resultant inductance is changed ^{in value} between the first time interval and ^{the} second time interval ^{more} ~~mentioned above and more~~ specifically, resultant

inductance is changed from a low value to a high value, between the first time interval for which the starting time of supply of the current is to be minimized, and the second time interval for which, although a hold current is required, ^{an excessively} fast responsiveness is not required. ^{In such a system, no} ~~the~~ problems would occur ^{so long as supply} ~~in the case that~~ the power voltage does not change.

However, in particular, when the power supply actually used is a battery, ~~the~~ voltage changes cannot be avoided. A fuel injector needs to operate its valve body at high speed and stably, even when ^{the} power ^{supply} voltage changes ~~occur~~. For this reason, ^a greater magnetomotive force, in other words, ^a larger integer value of the ampere-turns within the required time, is preferable.

However, in the case of the patent document 1 mentioned above, ^{which result from} no consideration is given to changes in magnetomotive force ~~due to~~ ^{the supply} changes in power voltage.

An object of the present invention is to provide ^{system} a fuel injector ~~that~~ ^{in which} ~~can suppress~~ changes in the amount of injection from its fuel injection valve ^{can be suppressed and} ~~by solving~~ the above-described problems, ^{can be solved by} and operating the valve body at high speed and stably, even when power ^{supply} voltage changes occur, ^{to} and thereby obtain stable fuel injection characteristics ^{It is another object of the present invention} ~~and~~ ^{to provide an improved} method of controlling the fuel injector.

^{associated with} In the present invention, ⁱⁿ which ~~is intended to achieve~~ high-speed and stable operation of ~~the~~ ^a valve body ^{of a fuel injector is achieved} by providing connection ^{the} changeover control of coils, when power ^{supply} voltage changes occur in the coil-equipped fuel injection valve, the problems described above can be

solved ~~by using the following means:~~ $\frac{\bullet}{\lambda}$

In ^a ~~the~~ ^{system} fuel injector, that comprises a direct-current power supply, a ^{supply} power voltage detection means, a coil-equipped fuel injection valve, and a control unit for controlling said fuel injection valve, the control unit outputs a changeover signal for changing the magnitude of resultant inductance of the coil in accordance with a power ^{supply} voltage detection value ^{received} ~~sent~~ from the power voltage detection means.

Also, in ^{accordance with} the present invention, a reference value of the power ^{supply} voltage is set beforehand, and the control unit outputs a control signal so that when a detected power ^{supply} voltage value is less than the foregoing reference value, the resultant inductance of the coil is reduced, and when the detected power ^{supply} voltage value is greater than the foregoing reference value, the resultant inductance of the coil is increased.

In addition, in ^{accordance with} the present invention, the fuel injection valve has a plurality of coils, and when ^{the} resultant inductance is to be set to a large value, the above-mentioned plurality of coils are connected in series, and when ^{the} resultant inductance is to be set to a small value, the above-mentioned plurality of coils are connected in parallel.

According to the present invention, even when power ^{supply} voltage changes occur, it is possible to operate the valve body at high speed and stably and ^{to} stabilize the amount of fuel injection with respect to the same injection command pulse width. Accordingly, it is possible to provide a fuel injector that can stabilize the operational status of an internal - combustion engine.

Brief Description of Drawings:

Fig. 1 is a block ^{current} diagram representing an embodiment of the fuel ^{system according} injector ~~pertaining~~ to the present invention;

Fig. 2 is a cross-sectional view representing an embodiment of the
5 fuel injection valve constituting the fuel injector of the present invention;

Fig. 3 is a timing chart ^{illustrating} ~~explaining~~ the operation of the fuel injector ^{according} ~~pertaining~~ to the present invention;

Fig. 4 is a diagram showing the relationship between the fuel
injection pulse and the amount of fuel injection;

10 Fig. 5 is another timing ^{illustrating} chart ~~explaining~~ the operation of the fuel injector, ^{according} ~~pertaining~~ to the present invention;

Fig. 6 is a ^{table} ~~diagram~~ showing the operation of the changeover
switches of the fuel injector ^{according} ~~pertaining~~ to the present invention, ^{as well as} ~~and~~ the
connection relationship between coils;

15 Fig. 7 is a flowchart ^{showing the operation of} ~~explaining~~ the fuel injector of the present
invention;

Fig. 8 is a diagram ^{showing} ~~explaining~~ the relationship between changes in
^{supply} power, voltage and changes in the amount of fuel injection;

Fig. 9 is a ^{diagram} ~~view~~ showing another embodiment of the present
20 invention;

Fig. 10 is a ^{schematic circuit diagram} ~~view~~ showing yet another embodiment of the present
invention; and

^{Figs. 11A and 11B are graphs}
~~Fig. 11 is a diagram~~ that shows ^a examples in which V_{th} is varied
according to a particular fuel pressure or ^{the} particular resistance value
25 ~~of harness~~ ^{respectively}.

Description of the Invention:

In ^a ~~the~~ ^{system} fuel injector that comprises a direct-current power supply, a power ^{supply} voltage detection means, a coil-equipped fuel injection valve, and a control unit for controlling the fuel injection valve, the fuel injection valve has a plurality of coils, and the control unit outputs a changeover signal for changing the magnitude-of-resultant inductance of the plurality of coils of the fuel injection valve in accordance with a power ^{supply} voltage detection value ^{received} ~~sent~~ ^{supply} from the power voltage detection means.

The control unit is also adapted to set a reference value of a power ^{supply} voltage beforehand and ^{to} output a changeover signal by which, when a value that has been detected by the power ^{supply} voltage detection means is less than the reference value that has been set beforehand, the resultant inductance of the coils is reduced, and when the power ^{supply} voltage detection value is greater than the reference value, the resultant inductance of the coils is increased.

Fig. 1 is a block diagram representing an embodiment of the fuel injector ^{system} according to the present invention. Fig. 2 shows ^{an example of} the composition of the fuel injection valve constituting ^{the principal element of} the fuel injector ^{system} to which the present invention applies.

First, the basic operation of the fuel injection valve ^{will be} is described ^{with reference to} below using Fig. 2. ^{which} Fig. 2 is a cross-sectional view showing an ^{example} ^{typed} ^{to be used in} ^{system} embodiment of the fuel injection valve constituting the fuel injector of the present invention. An orifice plate 1 is provided with a fuel injection orifice 2 and a valve seat 3. The orifice plate 1 is fixed to an end portion of a nozzle holder 11, ^{by} ~~by using a method~~ such as welding. A ^{fuel} swirler 12

for swirling fuel is provided between the orifice plate 1 and the nozzle holder 11.

Also, a guide plate 13 is fixed inside the nozzle holder 11. A valve body 4 is guided in ^{reciprocal} ~~sliding~~ ^{movement} condition by a hole provided in the center of the guide plate 13, and ^{by} an inside-diameter section of the swirler 12.

The valve body 4 comprises a movable iron core 5, a tubular member 6, and a rod 7, all of which are connected ~~by using a method~~, such as ^{by} welding. A damper plate 8 provided inside the movable iron core 5 has an outer-surface section ^{that is} supported ~~vertically~~ by an upper edge of the tubular member 6.

An interlocking member 10 is slidably supported in an axial direction ^{an internal} inside an inner fixed iron core 9. The interlocking member 10 has ~~a front~~ ^{that is} end brought into contact with an inner-surface section of the damper plate 8. The damper plate 8 has its outer-surface section ^{fixedly} supported, and its inner-surface section ^{is} axially warped, ^{thereby} ~~hereby~~ functioning as a plate spring.

The nozzle holder 11 is fixed to the inside of a nozzle housing 14. A ring 15 for adjusting ^{the} stroke of the valve body 4 is provided at an upper end of the nozzle holder 11. A spring pin 19 is fixed inside the inner fixed iron core 9. With a lower end of the spring pin 19 ^{spring} ^{upper} as its fixed end, a spring 20 is provided in a compressed condition ^{inside the inner fixed iron core 9} ^{from the spring 10}.

Numerical 21 denotes a fuel supply port. Spring force is transmitted to the valve body 4 via the interlocking member 10 and the damper plate 8, and the ^{rod 7 of the} valve body 4 is pressed against the valve seat 3. Under this ^{at the fuel injection surface 2} closed status of the valve, since the fuel passageway is closed, fuel that has been supplied from the fuel supply port 21 stays inside the fuel

injection valve, and ^{thereby} ~~hereby~~, fuel is not injected from the fuel injection orifice 2.

A magnetic circuit ^{described} ~~formed~~ around a first coil 100 and a second coil 101 is constituted by the nozzle housing 14, the movable iron core 5, the inner fixed iron core 9, a plate housing 16, and an outer fixed iron core 17.

When an injection command pulse turns on, a current flows into a series circuit formed by the first coil 100 and the second coil 101, ^{so that} ~~then~~ the movable iron core 5 is attracted to the inner fixed iron core 9 by electromagnetic force, and the valve body 4 moves to a position at which its upper edge comes into contact with the lower edge of the inner fixed iron core 9.

Under this open status of the valve, since a clearance is created ^{rod 7 of the} between the valve body 4 and the valve seat 3, the fuel passageway is opened and fuel that has been supplied from the fuel supply port 21 is swirled by the swirler 12 and injected from the fuel injection orifice 2.

When the injection command pulse turns off, the flow of the current into the first coil 100 and the second coil 101 is stopped, and since the

electromagnetic force disappears, the valve body 4 returns to a closed status ^{in which the valve body 4 slides downward until the rod 7 comes into contact with the valve seat 3 in response to the} ~~by~~ spring force to terminate the injection of the fuel.

The function of the fuel injection valve is to control the amount of fuel supplied, by changing ^{the position of} the valve body 4 ^{between} an open status ^{and} a closed status, depending on the injection command pulse status, ^{as well as} ~~and then~~ to adjust ~~the~~ the retention time of the open valve status.

To precisely control the amount of fuel supplied to an internal-combustion engine, it is important that the amount of fuel injection with

respect to the same injection command pulse width should always be stable.

An embodiment of the fuel injector ^{system}, according to the present ~~invention~~ ^{will be} described below ^{with reference to} using Fig. 1.

5 In Fig. 1, a power supply 103 and a current detector 104, together with a first switch 105, a second switch 106, and a third switch 107, are connected to a first coil 100 of a fuel injection valve and to a second coil 101 thereof.

The power supply 103 here can be either a battery mounted in a
10 vehicle or a high-voltage generator consisting of a combination of a battery and a booster circuit which includes, for example, a DC/DC converter. The power supply can be any device, provided that it can supply electric power to the fuel injection valve. To make the fuel injection system less expensive, however, it is preferable that the power
15 ^{in the form of} supply be a battery for a vehicle.

Although it is preferable that the current detector 104 be ^{of the type which uses} ~~able to use~~,
a current detection resistor, the type of current detector 104 is not limited
^{thereto} ~~by this statement~~ and other means can be used alternatively, provided
that it can detect current values. ^{The} voltage of the power supply 103 is
20 measured by a voltage detection means 108, and its detected voltage V_{103} is sent to a control unit 102.

The current ~~is~~ flowing into the first coil 100 and the second coil 101, or the sum of the currents flowing into both coils, is measured by the current detector 104, and the results are sent to the control unit 102.

25 Although not shown in the figure, operational status information, such as

~~the~~ internal-combustion engine speed, is also input to the control unit 102.

Inside the control unit 102, ~~the~~ ^{an} injection command pulse corresponding to the amount of fuel injection required according to a particular operational status of the internal-combustion engine is created, and a signal for controlling the changeover between the first switch 105, the second switch 106, and the third switch 107, is output, based on that injection command pulse.

A certain voltage judgment reference value (V_{th}) is provided for the voltage detection value that has been measured by the voltage detection means 108 of the power supply 103. The fuel injector operation ~~is~~ ^{and the operations, which, are controlled on the basis of whether} switch opening/closing, ~~under the status that~~ ^{or less} the voltage detection value is greater ^{will be} than the voltage judgment reference value ~~is~~ ^{with reference to} described below ~~using~~ Fig. 3.

When, as shown in Fig. 3 (A), an injection command pulse signal 110 turns on at " t_0 ", the control unit 102 outputs a control signal ~~for~~ ^{for}, as shown in Fig. 3 (C), connecting the first switch 105, the status of which is represented ~~by~~ ^{by} numeral 117, and, as shown in Fig. 3 (D) and ^{Fig. 3} (E), ~~it~~ ^{it outputs control signal} for disconnecting the second switch 106 and the third switch 107, the status of which is represented ~~by~~ ^{by} numerals 118 and 119. ^{respectively}

Thereby, the first coil 100 and the second coil 101 are connected in series ~~with respect~~ ^{produced by the series connection} to the power supply 103. The resultant inductance of the first coil 100 and the second coil 101, when viewed from the power supply 103, increases.

The voltage at both ends of the series-connected first coil 100 and second coil 101, namely, the voltage between points A and D, takes the

waveform ~~shown as numeral~~ ^{shown} 111 in Fig. 3 (B). Here, the current flowing through the series-connected first coil 100 and second coil 101, namely, the current I flowing between points A and D, can be ^{caused to} rapidly increase by appropriately setting the relationship between the voltage and the resultant inductance and resistance value of the coils.

Accordingly, ^{the} magnetomotive force (ampere-turns) ^{which} ~~that~~ is the product of this current value and the total number of turns of the first coil 100 and second coil 101, also rapidly increases. This state is shown ^{by the curve} ~~as numeral~~ 112 in Fig. 3 (F).

Since the magnetic attraction force exerted on the valve body 4 also increases rapidly, the displacement thereof takes the form shown ^{by curve} ~~as~~ numeral 113 in Fig. 3 (G), thus ^{causing} ~~opening~~ ^{to open} the valve at high speed. After a fixed time, that is to say, after the elapse of time T_1 as shown in Fig. 3 (F), the control unit 102 generates a control signal for repeating the disconnection and connection of the first switch 105 so that ^a ~~the~~ magnetomotive force becomes ^a relatively low retention magnetomotive force (fh).

After that, when the fuel injection command pulse turns off at "te", the control unit 102 generates a control signal for disconnecting the first switch 105. ~~Hereby,~~ ^{Since} the coil current disappears, the valve body returns to a valve-closing position. Under this operation sequence, the amount-of-injection characteristics ^{so} ~~represented~~ with the fuel injection command pulse width taken on the abscissa ^{is} ~~and~~ the amount of fuel injection ^{taken} ~~on~~ the ordinate, appear as a fuel injection characteristics curve

120 shown in Fig. 4.

However, the voltage of the power supply 103 frequently changes. In particular, when a battery for an automobile is employed as the power supply 103, the voltage could decrease to about 6 V, as represented by numeral 114 in Fig. 3 (B). In other words, the voltage may change to a value smaller than the voltage judgment reference value V_{th} .

At this time, supposing that the resultant inductance of the coils is great, as described above, since the current flowing through the coils would also decrease, the response characteristics of the magnetomotive force would decrease, hereby taking ~~such a~~ ^{the} form as denoted by numeral 115 in Fig. 3 (F). Because of the ~~lack of~~ ^{lack of} magnetomotive force (ampere -turns) ~~lacking~~, the displacement of the valve would take ~~such~~ ^{at all} a form as denoted by numeral 116 in Fig. 3 (G), thus making valve opening incomplete. In extreme cases, the fuel injection valve might not open.

More specifically, the amount-of-injection characteristics of the fuel injection valve might appear as ~~a~~ ^{the} characteristics curve 121 or 122 shown in Fig. 4. In other words, even if the same injection command pulse width is assigned, the amount of fuel injection would decrease. If this is the case, since the amount of fuel injection, ~~according to~~ ^{required for} the particular operational status of the internal -combustion engine cannot be supplied, ~~a problem~~ ^{trouble} will be caused ~~to~~ ⁱⁿ the operation of the internal -combustion engine.

Under this operation sequence, the amount-of-injection characteristics, ~~represented with the fuel injection command pulse width taken on the abscissa,~~ ^{as} and the amount of fuel injection, ~~on~~ ^{taken}, on the ordinate, would change from the characteristics ~~shown as~~ ^{shown} 120, in Fig. 4, to the characteristics ~~shown as~~ 121 or 122.

In order to solve this problem, the considerations described below are incorporated into the present embodiment. The operation of the fuel injector, ~~existing~~ when the voltage value of the power supply 103 is smaller than the above-mentioned voltage judgment reference value V_{th} , ~~is~~ ^{will be} described below ^{with reference to} using Fig. 5.

5 ~~When~~ ^{Under the status of} ~~the status of~~ $V_{103} \leq V_{th}$, ~~when~~ ^{and} the injection command pulse ~~turns on at "t₀"~~ ^{seen} as ~~represented by numeral 110~~ ¹¹⁷ in Fig. 5 (A), the control unit 102 outputs a control signal ^{seen} for disconnecting the first switch 105, as ~~represented by numeral 117~~ ^{it outputs control signals 118 and 119 for} in Fig. 5 (C), and connecting the second switch 106 and the third switch 107, ^{seen} as ~~represented by numerals 118 and 119~~ ^{Fig. 5} in Fig. 5 (D) and (E). ^{Thus} ~~Hereby~~, the first coil 100 (N1) and second coil 101 (N2) shown in Fig. 1 are connected in parallel ~~with respect~~ ^{produced by the parallel connection} to the power supply 103.

Accordingly, the resultant inductance ^{will} of the first coil 100 and the second coil 101, when viewed from the power supply 103, ~~can~~ ^{can} be reduced. ~~Hereby~~ ^{now}, since ^a high-speed response of the magnetomotive force can be obtained, it becomes possible to obtain ~~such a~~ ¹¹² magnetomotive force waveform ^{seen} as ~~represented by numeral 112~~ ¹¹² in Fig. 5 (F). Consequently, as represented by numeral 113 in Fig. 5 (G), the displacement of the valve body can be ~~made~~ ^{made} fast and stable.

After a fixed time, that is to say, after the elapse of time T_j as shown in Fig. 5 (F), the control unit 102 generates a control signal for repeating the disconnection and connection of the second switch 106 and third switch 107 so that the total magnetomotive force becomes ^a relatively low retention magnetomotive force (f_h).

To control ^{the} retention magnetomotive force "fh" by connecting the two coils in parallel, it is preferable that the current value of the current detector 104 should be controlled so as to be about twice the current value thereof obtained in the case of ^a series connection ^{of the coils}.

5 When the fuel injection command pulse turns off, the control unit 102 generates a control signal for disconnecting the second switch 106 and the third switch 107, ^{thereby} ~~hereby~~ making the coil current disappear and returning the valve body to a valve-closing position.

Here, the series/parallel connection relationship ^{caused by control of} ~~between~~ the first switch 105, the second switch 106, ^{and} the third switch 107, ^{between} the first coil 100, and the second coil 101, is arranged in order. This arranged state of the relationship is shown in Fig. 6. When $V_{103} > V_{th}$, this denotes a normal status. Conversely, when $V_{103} \leq V_{th}$, changeover control is conducted for the switches, ^{supply} since the power ^{supply} voltage is judged to be too low.

15 In this way, providing the judgment reference value V_{th} for the changeover of the switch connection ~~from~~ makes it possible to switch the series/parallel connection of the first coil and the second coil when the ^{supply} power voltage becomes equal to, or less than, the above reference value.

It becomes possible, by doing so, to obtain the same valve-opening characteristics ^{in a low battery state} as those obtained in the case of ^{a normal battery state} ~~series connection~~.

20 This status is shown ^{by} ~~as~~ solid lines in Fig. 3 (F) and ^{Fig 5} (G) and Fig. 5 (F) and ^{Fig 5} (G). Therefore, stable injection characteristics can be obtained without changes in the fuel injection characteristics 120 of Fig. 4.

The process ^{carried out} ~~the~~ flow in the control unit 102 is shown in Fig. 7. In step 7a, it is judged whether the power ^{supply} voltage V_{103} or the voltage

judgment reference value V_{th} is greater. If the relationship of $V_{103} \leq V_{th}$ holds, ~~the~~ parallel connection between the first coil 100 and the second coil 101 is ^{affected} changed in step 7c.

That is to say, the connection is changed by turning off the first switch 105 and turning on the second switch 106 and the third switch 107. See Fig. 6. Conversely, when $V_{103} > V_{th}$, this status is judged to be normal, and the coils remain connected in series, as shown in step 7b. Also, see Fig. 6.

Under this operation sequence, the amount-of-injection characteristics, ^{gas} represented with the fuel injection command pulse width taken on the abscissa, and the amount of fuel injection, ^{taken} on the ordinate, take the form shown ^{by} as 120 in Fig. 4, and regardless of a low-voltage status, it becomes possible to maintain a status as stable as the fuel injection characteristics ^{that are} obtained when the voltage is high.

More specifically, even when the power, ^{supply} voltage changes, it becomes possible to suppress changes in the amount of fuel injection with respect to the same injection command pulse width, and thus to always stabilize the amount of injection. Hereby, the ^{proper} amount of fuel injection according to the particular operational status of the internal-combustion engine can be supplied, and this, in turn, enables stabilized operation of the internal-combustion engine.

Next, the relationship between power, ^{supply} voltage changes and ^{the} fuel injection characteristics ^{will be} is described ^{with reference to} below using Fig. 8. Suppose that ^{the} normal power, ^{supply} voltage V_{103} is 14 v. The amount of fuel injection at this time is expressed as F_n . ^A ^{in which} ^{supply} The case ~~that~~ this power, ^{supply} voltage V_{103}

will be considered by way of example
decreases to 7.0 (v) ~~is described here~~. In this case, when V_{103} is set to 7.0 (v), the connection between the first coil 100 and the second coil 101 is changed at this time.

More specifically, a coil changeover signal is output from the control unit 102 and the connection between the first coil 100 and the second coil 101 is changed from series connection to parallel connection. If both coils remain connected in series at $V_{103} = 7.0$ (v), the amount of fuel injection decreases to $F1 (< F_n)$. The amount of injection, however, can be recovered to the vicinity of F_n by changing the connection of the coils to a parallel connection.

Fig. 8 shows an example in which the connection between ~~both~~ the coils is changed when $V_{103} = 7.0$ (v). However, ~~the~~ an optimum value needs to be set since the characteristics in Fig. 8 change according to the fuel injection characteristics relative to ~~against~~ the power supply voltage, more particularly, according to the characteristics of the fuel injection valve.

In general, it is desirable that ~~when~~ the voltage V_{103} decreases to a range from about 7.0 to 9.0 (v), the connection between the coils should be changed. Or conversely, after the tolerance of changes in the amount of fuel injection has been determined, the above-described changeover control can be conducted when the tolerance is reached.

For example, since characteristics "Fc" exhibit a nonlinearity with changes in the supply respect to power supply voltage changes, when the power voltage decreases to half its original value, " $F1 = (1/2) F_n$ " does not always hold. Therefore, the connection between the coils 100 and 101 can also be changed when the condition of " $(F_n - F_c) > F_g$ (required value)" is established.

In general, changes in the voltage of the power supply 103 cannot

be avoided. In particular, when an automotive battery is employed as the power supply 103, the voltage could decrease to about 6 V, as represented by numeral 114 in Fig. 3 (B).

At this time, if the resultant inductance of the coils is great, as described above, the response characteristics of the magnetomotive force are apparently tantamount to having decreased, and the magnetomotive force takes ~~such~~ ^{lack of} a form as denoted by numeral 115 in Fig. 3 (F). Because of the magnetomotive force ~~lacking~~, the displacement of the valve takes ~~such~~ a form as denoted by numeral 116 in Fig. 3 (G), thus making valve opening incomplete.

The amount-of-injection characteristics appear as a characteristics curve 121 or 122 ~~shown~~ in Fig. 6, and thereby, there occur changes in the amount of fuel injection with respect to the same injection command pulse width. ~~Hereby,~~ ^{Since} the amount of fuel injection according to the particular operational status of the internal -combustion engine cannot be supplied, ^{a problem} ~~trouble~~ will be caused ⁱⁿ to the operation of the internal - combustion engine.

Also, it would be possible to use the following methods to judge whether the power ^{supply} voltage V_{103} or the voltage judgment reference value V_{th} is greater.

The methods that can be actually used, however, are not limited to these methods: for example, the relationship in magnitude between the ^{supply} power voltage value and the voltage judgment reference value can be judged by converting a detected voltage value into digital signal form by means of an A/D converter provided in either the voltage detection means

108 or the control unit 102, and then using a microcomputer provided in ^{to detect the relationship} the control unit 102. Or, the relationship in magnitude can be judged by ^{supplying} entering the power voltage value and the voltage judgment reference value into a comparator.

5 In addition, there is another method of ensuring ^{that} the opening operation of the valve, ^{will open even} when the power voltage decreases. As described above, when the power ^{supply} voltage decreases, the ^{rise} start of augmentation of the magnetomotive force apparently ^{is reduced} delays as shown in 115 of Fig. 3 (F), and, therefore, ^{it may not be possible to obtain} the magnetomotive force actually required, ^{to open the valve} cannot be
10 obtained.

At this time, by increasing the value of T, which is the time for ^{increasing} changing the magnetomotive force to ^a retention magnetomotive force, the ^{delay which the magnetomotive force increases} changeover time can likewise be adjusted so that the magnetomotive ^{to} force becomes great enough to open the valve. ^{there is sufficient time for} This method is also
15 valid for ensuring valve opening.

However, since this method extends the time required for the magnetomotive force to become great enough, ^{to open the valve} the amount of injection characteristics are likely to take the form represented ^{by measurement} as 121 in Fig. 4. For this reason, ^{will occur} there occurs a change in the amount of fuel injection
20 corresponding to the same injection command pulse width. Of course, it is also possible, after estimating this spread of change, to provide control so that the injection command pulse width is adjusted.

To simplify engine control, however, it is desirable that the amount of fuel injection corresponding to the same injection command pulse width
25 should always be constant. The present embodiment is advantageous

in that the amount of fuel injection corresponding to the same injection command pulse width is always constant.

Furthermore, there is yet another method of ensuring ^{that} the opening ^{will open even} operation of the valve, when the power, ^{supply} voltage decreases. That is to say, valve opening can be achieved by applying ^a voltage only to either the first coil 100 or the second coil 101 when the power, ^{supply} voltage decreases. This method can also be ^{effective when a} such that voltage is applied only to a portion of the coil-wound section of the fuel injection valve. →

The use of this method also makes it possible to reduce the resultant inductance of the coils when viewed from the power supply 103, and ^{thereby} ~~hereby~~ to augment the magnetomotive force abruptly. However, since the magnetomotive force is ^{only} consequently applied to a portion of the coil space of the fuel injection valve, ^{the} current density increases and this poses the problem that the coil temperature increases very significantly.

In the present embodiment, however, since ^a magnetomotive force is applied to the entire coil space of the fuel injection valve, ^{and thus} ~~and thus~~ since ^{the} ~~the~~ current density is controlled to a relatively small value, there is the advantage that increases in the coil temperature can be minimized.

Next, the strand diameters and number-of-turns of the first coil 100 and second coil 101 in the present embodiment ^{will be} ~~are~~ described ^{below}. It is desirable that the first coil 100 and the second coil 101 should ^{have} ~~be~~ the same ^{same} strand diameter and ~~the~~ number of turns. In this case, the responsiveness of the magnetomotive force can be controlled to the same level between both coils, even if the power, ^{supply} ~~power~~ voltage decreases to about half its original value.

However, even if the strand diameters and number-of-turns of the first coil 100 and second coil 101 are set to different values, ~~there is not a change in that~~ ^{still} the resultant inductance of the two coils ~~can~~ ^{can} be reduced by connecting both coils in parallel, and the effects of the present invention are not degraded.

For the present embodiment, as shown in Fig. 3, the scheme in which ~~magnetomotive force is changed to~~ ^a retention magnetomotive force has been described. The effects of the present invention can likewise be obtained by adopting a scheme in which, after a reference value has been provided for the maximum magnetomotive force beforehand, ~~the~~ ^a magnetomotive force is changed to ^a retention magnetomotive force at the time of detection of the fact that this reference value has been reached.

In the present embodiment, as shown in Fig. 2, the first coil 100 and the second coil 101 are arranged ^{adjacent to each other} in the axial direction of the fuel injection valve. ~~It~~ ^a is also possible to adopt coil arrangement in which the first coil 100 ^{is disposed} at the inside-diameter side of the fuel injection valve and the second coil 101 ^{is disposed} at the outside-diameter side.

~~This is a method of arranging the coils at right angles,~~ ^{two} ~~not axially,~~ ^{radially} with respect to the fuel injection valve. It is advantageous to adopt this method in ^a ~~the case that~~ ^{in which} ~~that~~, for example, there are spatial margins in the radial direction of the fuel injection valve, rather than in the axial direction thereof. A schematic view of such ^{an} arrangement is shown in Fig. 9 ~~the~~.

Furthermore, although ~~the method of~~ a method of electrical connection between the first coil 100, the second coil 101, and the power supply 103, ^{in Fig. 1} has been shown, the electrical connection method, the number of

the example shown
switches, the number of coils, and other factors are not limited by Fig. 1.

When three or more coils are provided, *so long as* ~~provided that~~ the connection status of these coils, when viewed from the power supply, can be changed from series connection to parallel connection, or vice versa,

5 the present invention can also be applied in that case. An example of *a multiple coil arrangement* application in such a case is shown in Fig. 10. In this example, N1 and N2 are the same as in Fig. 1. *coils 100 and 101* ~~two~~ *these two* coils are connected in series to a switch 105. ~~Parallel connection is omitted.~~ *and* ~~described~~ *these* ~~Additional~~ *Additional* coils N3 and N4 are connected *to switches 108 and 109, respectively.*

Also, in the above embodiment, although a method of changing
10 *the* resultant inductance has been described, *based on* ~~showing~~ an example in which the power *supply* voltage changes, the response of the current may also deteriorate if changes in resistance occur in the coils or in the electrical wiring (namely, harness) for supplying the current to the coils. →

15 If that is the case, the amount-of-injection characteristics can be stabilized by, for example, detecting *the* resistance values directly or indirectly and then increasing or reducing *the* resultant inductance, depending on the resistance values, by use of the method described above.


Referring to the example of Fig. 1, it has been earlier described that
20 when a battery supplying a ~~power~~ voltage of 14 (V) is used, the appropriate voltage judgment reference value V_{th} for series/parallel connection changeover of the coils is from 7 to 9 (V). The voltage judgment reference value V_{th} , however, can be varied according to other conditions. →

25 For example, V_{th} can be varied according to a particular fuel

pressure or the particular resistance value of the harness. Examples are shown in ~~Fig. 11~~ ^{Fig. 11(A) and 11(B)}.

Fig. 11 (A) shows an example in which the voltage judgment reference value V_{th} is varied according to ~~a~~ ^{the} fuel pressure.

Fig. 11 (B) shows an example in which the voltage judgment reference value V_{th} is varied according to particular changes in the resistance value of the harness.

Furthermore, it may be advisable to vary the responsiveness of ~~the~~ ^{the} magnetomotive force according to a particular fuel pressure level. For example, when the fuel pressure is high, it may be possible for the opening of the valve to be stabilized by reducing the responsiveness of the magnetomotive force. 

In this case, the amount-of-injection characteristics can be stabilized by detecting the fuel pressure directly or indirectly and then increasing or reducing ~~the~~ ^{the} resultant inductance, depending on that pressure value, by use of the method described above.

In addition, the effects of the present invention are not limited to the case of ~~using the~~ ^{use of a} fuel injection valve having ~~such~~ ^a composition as shown in Fig. 2. The effects of the present invention can be obtained for any type of fuel injector, provided that ~~a~~ ^{the} fuel injection valve ~~which~~ ^{supply} has coils and a magnetic circuit is included in the fuel injector.

According to the present invention, even in ~~case of~~ ^{supply} power voltage changes or the like, it is possible to operate the valve body at high speed and stably, ~~hereby~~ ^{stably} to stably maintain the amount of fuel injection with respect to the same injection command pulse width, and, consequently, to obtain a fuel injector that can stabilize the operational status of an

internal-combustion engine. According to the present invention, the amount of injection is stably maintained, even when power, ^{supply} voltage changes occur.

5 The present invention can be used for ~~such~~ ^{of the type as} an electromagnetic valve, that uses electromagnetic force to provide fuel supply control, as well as for an automotive fuel injection valve.